MECHATRONICS BOOK SERIES

CONTROL AND INTELLIGENT SYSTEMS

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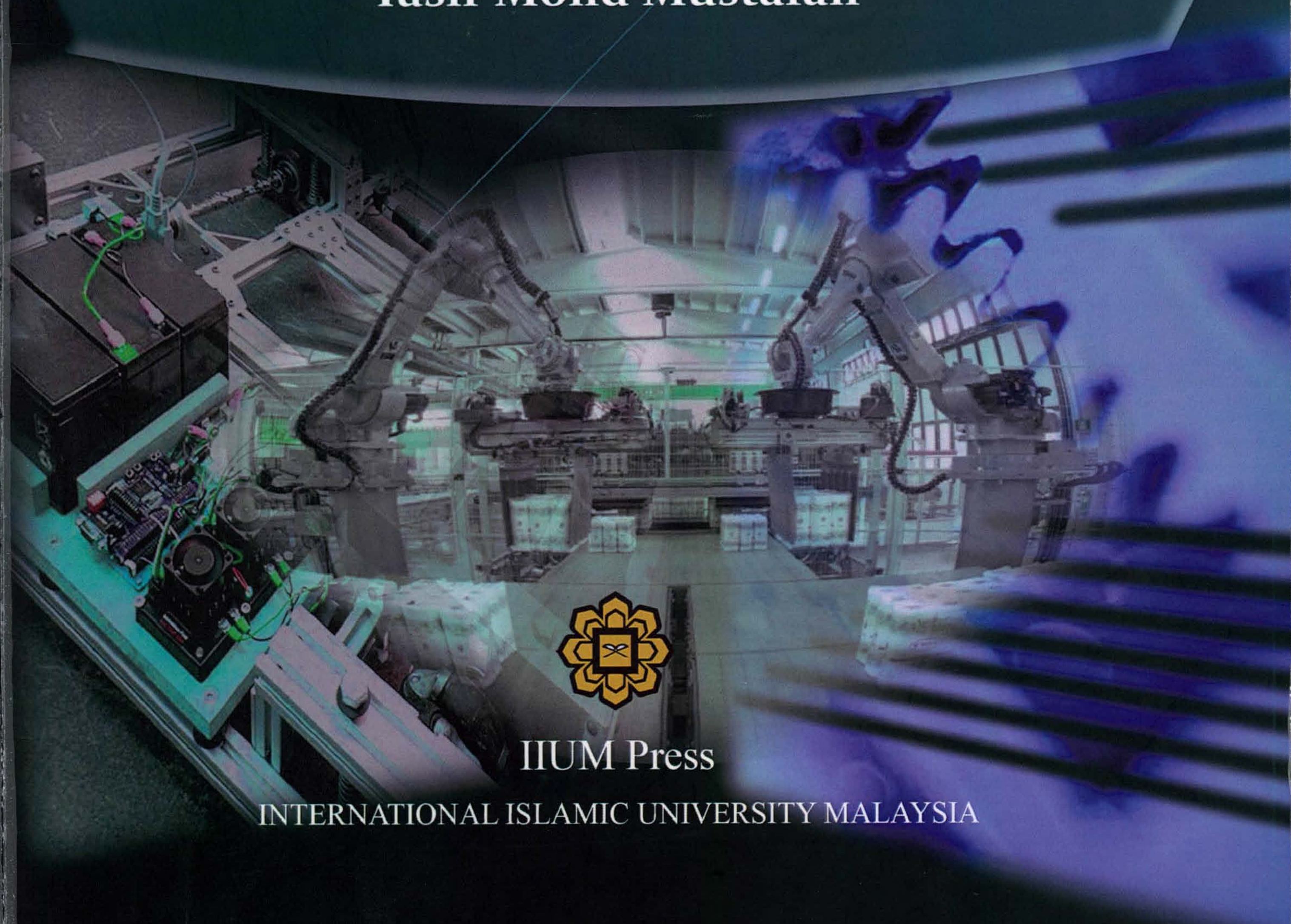
Abiodun Musa Aibinu
Yasir Mohd Mustafah



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Chapter 1
Working Principle and Operating Mode of Atomic Force Microscopy

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1.1 Introduction

This chapter describes one aspect of Scanning Probe Microscopy (SPM), i.e., Atomic Force Microscopy (AFM). In order to provide an overview of AFM, different types of SPM and their applications are first discussed. This is then followed with discussions on the working principle of AFM that includes descriptions of the tip-sample interaction used in AFM and the basic components of AFM.

1.2 Scanning Probe Microscopies

The invention of scanning tunneling microscopy (STM) [1, 2] by G. Binnig and his colleagues in 1982 has led to the development of various kinds of scanning probe microscopies (SPMs) such as Scanning Near-field Optical Microscopy (SNOM) [3], Atomic Force Microscopy (AFM) [4] and Scanning Magnetic Microscopy (SMM) [5]. These groups of microscopies are referred to as SPM due to the use of probe in these devices for investigation and manipulation of material surfaces down to the atomic scale. Attached to the probe's free end is an extremely sharp tip whose geometrical shape determines the lateral resolution limit of the microscope [6]. Ideally, the tip should be atomically sharp in order to achieve the atomic resolution. The tip is positioned very close to the sample surface during a scan. At such a close distance, there exist some highly localized tip-sample inter-action that can be used to obtain local information and SPM images of the material surfaces. For example, the type of tip-sample interaction used in STM is the tunneling current that flows between a conductive tip and a conductive surface; in AFM is the interactive force between a tip and a sample surface; and in SMM is the magnetic force between a magnetic coated tip with local magnetic field of a sample surface.

Since their invention, SPMs have become important research instruments in various applications of nanoscience and nanotechnology due to their capabilities to examine sample surfaces down to the atomic scale. Example of these applications include imaging of surface topography of Si(111)7×7 at atomic resolution using STM [2] and AFM [7], measuring of magnetic forces in recording media using SMM [8] and imaging of molecular topography of a deoxyribonucleic acid (DNA) helix using AFM [9]. STM and AFM are also used in applications that involve manipulation of matter at nanoscale. In [10], while operating under low temperature, an STM was used to position individual xenon atoms on a single-crystal nickel surface with atomic precision. The AFM capability to position individual atoms at the desired atomic positions was also demonstrated in [11, 12].

Among the family of SPMs, AFM has become the most widely used microscope to produce topographic images of material surfaces at nanoscale. This is mainly because it can be used to image any material surface, unlike STM where the sample is required to be conductive and most SNOMs where the sample is required to be optically transparent [13]. The AFM's ability to measure the interactive forces also has led to the modification of the AFM probe for